Jurnal Kependidikan:
Jurnal Hasil Penelitian dan Kajian Kepustakaan di Bidang Pendidikan, Pengajaran dan Pembelajaran
https://e-journal.undikma.ac.id/index.php/jurnalkependidikan/index

Vol. 12, No. 2 : June 2026
E-ISSN: 2442-7667
pp. 971-980
Email: jklppm@undikma.ac.id

An Exploratory Factor Analysis for Measuring the Four Cs of Lower-grade Primary Students

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AbstractThis study aims to develop a valid and reliable measurement factor for the Four Cs tailored to lower-grade primary school students. This study employed a quantitative non-experimental scale development and validation design utilizing Exploratory Factor Analysis (EFA). Participants comprised 274 second-grade primary school students from ten schools, divided into two phases: an initial trial (n = 76) for item selection and a main EFA trial (n = 198). Data were collected through structured performance observation checklists administered during STEM-based constructive play activities, with dichotomous scoring subsequently analyzed using JASP. EFA initially yielded six factors; however, the sixth factor, comprising a single item, was excluded from the final model as it did not meet the minimum item requirement for a viable factor. Factor loadings across the five retained factors ranged from 0.413 to 0.992. Cronbach's alpha coefficients indicated adequate to excellent internal consistency across factors: the first factor (α = 0.912), the second factor (α = 0.856), the third factor (α = 0.716), the fourth factor (α = 0.796), and the fifth factor (α = 0.544), with an overall reliability of α = 0.884. The findings indicate that the Four Cs can be measured by five factors: effective communication-critical thinking skills, creative expression skills, collaboration skills, communication skills in problem-solving, and creating skills. This study highlights different results from the P21 learning framework, finding that effective communication fosters problem-solving and critical thinking skills, while collaboration encourages creativity and the creation of original works.

Article History
Received: 24-03-2026
Revised: 29-04-2026
Accepted: 31-05-2026
Published: 20-06-2026

Key Words:
Measurement Factors; The Four Cs; Lower-Grade Primary Students; Validity; Reliability.

How to Cite: Ginting, M. B., Purba, R., Limbong, W. S. br, Amanda, A., & Sitanggang, D. R. (2026). An Exploratory Factor Analysis for Measuring the Four Cs of Lower-grade Primary Students. *Jurnal Kependidikan : Jurnal Hasil Penelitian Dan Kajian Kepustakaan Di Bidang Pendidikan, Pengajaran, Dan Pembelajaran*, *12*(2), 971-980. https://doi.org/10.33394/jk.v12i2.20384

https://doi.org/10.33394/jk.v12i2.20384

Introduction

The rapid advancement of technology and the complexity of social issues have reshaped the orientation of education. Today, global education emphasises the development of critical thinking and problem-solving skills, collaboration and communication skills, and creativity skills, collectively known as the Four Cs (Roekel, 2023). These skills should ideally be nurtured from the early grades of primary education, as students at this stage are highly responsive to stimuli, laying the foundation for future skill development (Santrock, 2018).

Despite its importance, the measurement framework for the Four Cs, as released by P21 Partnership for 21st-Century Learning (2019), remains highly general. For example, one critical thinking indicator states, "Applying a variety of reasoning methods, including inductive and deductive reasoning …" At this stage, the capacity for deductive reasoning and

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E-ISSN: 2442-7667
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abstract systems thinking, both implicitly demanded by the aforementioned P21 indicators, has not yet emerged as a reliable cognitive concrete operational stage competency (De Koning et al., 2002; Perret, 2015).

Similarly, in Indonesia, the development tasks of the Four Cs for first and second graders (Phase A) are structured into four dimensions. The first, critical thinking and problem-solving skills, are assessed based on students' ability to process information, analyse reasoning, and reflect on their thinking. The second, communication skills, involves recognising oneself and others, expressing views on general topics, and listening to different perspectives. The third, collaboration skills, focuses on accepting roles, working synergistically, and recognising individual and group needs. The fourth, creativity skills, include generating original ideas, thinking fluently to find solutions, and engaging in group activities (Permendikbudristek Nomor 5, 2022). While this framework is more specific than P21's, determining appropriate measurement items remains challenging.

A survey of 68 Phase A teachers from 32 primary schools confirms this difficulty. Using 29 reflective statement items assessing the frequency of Four Cs behaviors in daily classroom activities, the survey found that 31% of indicators were never demonstrated, 38% were rarely observed, 21% were frequently observed, and only 10% were consistently displayed, meaning that 20 of 29 indicators were rarely or never seen in practice. Subsequent classroom observations corroborated these findings: although students were assigned group tasks, collaborative behaviors such as confirming views, sharing responsibilities, or expressing ideas were seldom evident. Instead, a few dominant individuals completed tasks while others remained passive. This pattern reveals a fundamental misalignment between standardized performance indicators and the developmental characteristics of concrete operational learners.

The selection of developmentally appropriate measurement items is therefore critical. Creativity indicators across both P21 and Indonesian frameworks, emphasize idea generation, work creation, and innovation, yet early primary students' creativity is inherently intrapersonal and contextual, oriented toward openness and exploration rather than breakthrough innovation (Ershadi & Winner, 2020; Beghetto & Kaufman, 2007). Furthermore, existing Four Cs assessment tools primarily target higher education (Thornhill-Miller et al., 2023; Boyaci & Atalay, 2016), and even multidimensional assessments (Braun et al., 2020; Duru et al., 2022; Kowiyah et al., 2020), fail to address the specific needs of early primary learners.

To bridge this gap, this study compiled and adapted 90 measurement items from standardized instruments, including critical thinking and problem-solving items from Pollarolo et al., (2023); collaboration items from Ekeh (2023) and Hesse et al., (2015); communication items from Bishop (2015); and creativity items from Ershadi & Winner (2020). This study aims to identify the measurement factors of the Four Cs for lower-grade primary students through EFA. The findings are intended to enable teachers to conduct diagnostic assessments before designing targeted learning activities, thereby supporting the integrated and sustainable development of the Four Cs.

Research Method

A quantitative non-experimental scale development and validation design was employed, utilizing Exploratory Factor Analysis (EFA) to identify and validate the factor structure of the Four Cs competencies among lower-grade primary school students. A quantitative approach was selected because the research objective involves measuring

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observable student behaviors through numerical data and analyzing their underlying structure using multivariate statistical procedures (Creswell, 2014).

Participants comprised 274 second-grade primary school students from 10 schools in Medan city, divided into two groups. The first group (n = 76; 31 male, 45 female) from one school with three parallel classes was used for the initial item trial. The second group (n = 198; 103 male, 95 female) from nine other schools was used to test remaining items after the first elimination phase. All participants were aged 7 years and 9 months until 9 years old, situated at the concrete operational stage, characterized by understanding concepts through direct experiences with concrete objects (Zhou & Brown, 2015).

Data were collected through a structured performance observation checklist administered by trained observers during naturally occurring learning activities. Observers recorded student behavior in real time using a dichotomous scoring system, coding each item as 1 if the targeted behavior was observed and 0 if not, producing a binary response matrix for psychometric analysis.

Item development began with identifying Four Cs measurement items from standardized instruments and literature reviews, yielding 90 items initially. After removing redundant and less relevant items, 53 items were retained for testing, arranged as a performance checklist administered during STEM-based constructive play activities across three structured learning sessions per class. Each session followed a consistent sequence. The initial phase involved students discussing problem-solving strategies, allowing observation of collaboration and communication skills. The core phase focused on exploring team discussion outcomes, with observations targeting critical thinking, problem-solving, and creativity. The final reflection phase, conducted through Q&A, required successful teams to explain their strategy's advantages while unsuccessful teams identified reasons for failure, providing further opportunity to observe all Four Cs dimensions.

Trial data were analyzed using Pearson correlation tests. Items with $p > .05$ were considered invalid and removed (Goretzko et al., 2021), reducing the item pool from 53 to 44. A subsequent difficulty and discrimination analysis revealed that 80% of items had moderate difficulty, 14% were easy, and 6% were difficult. Four items (B1, B12, C2, D9) with discrimination power < 0.19 were removed, leaving 40 valid items, which were then administered to the 198 participant group using the same procedure.

All analyses were conducted using JASP version 0.19.0.0. EFA was employed to identify the underlying factor structure, reduce data complexity, assess construct dimensionality, and verify construct validity (Taherdoost et al., 2014; Watkins, 2018). Implementation followed four steps: (1) verifying multivariate normal distribution; (2) applying the Kaiser-Meyer-Olkin (KMO) test (MSA ≥ 0.50) and Bartlett's test ($p < .05$) to confirm sample adequacy; (3) extracting factors using maximum likelihood with oblique-promax rotation, guided by scree plot and path diagram, retaining items with factor loadings ≥ .40; and (4) interpreting the resulting factors (Goretzko et al., 2021; Watkins, 2018; Peterson, 2017).

Factor validity was evaluated descriptively across three aspects: factor loadings representing item-factor correlations; loading patterns, where high loadings across multiple factors indicate low specificity and reduced construct validity; and threshold consistency, where uniformly high and unambiguous loadings across all items in a factor support construct validity (Goretzko et al., 2021). Internal consistency reliability was assessed using Cronbach's alpha, interpreted according to criteria proposed by Taber (2016).

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Results and Discussion

The path diagram illustrates the six factors yielded by EFA, along with the items constituting each factor. Item codes reflect their source dimension: "A" denotes critical thinking and problem-solving, "B" denotes collaboration, "C" denotes communication, and "D" denotes creativity.

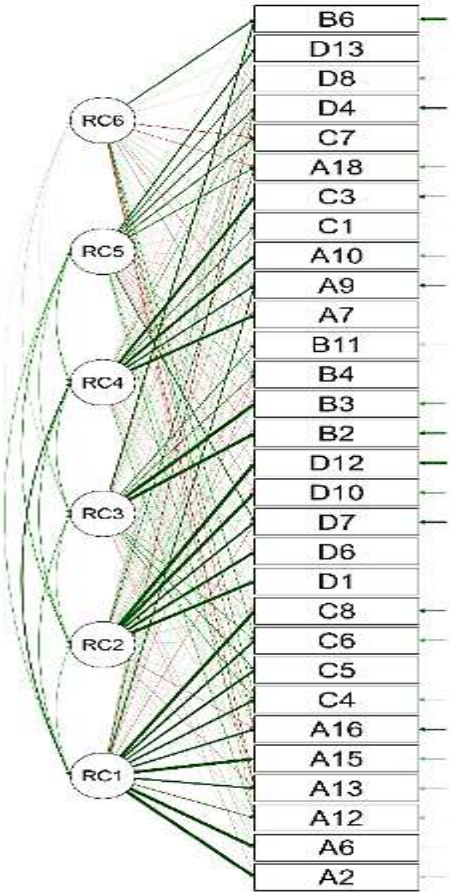

Figure 1. Path Diagram Visualisation

The first factor (RC1) comprises items from both the critical thinking and communication dimensions. The second factor (RC2) consists entirely of creativity items. The third factor (RC3) contains collaboration items. The fourth factor (RC4) combines critical thinking and communication items. The fifth factor (RC5) draws from critical thinking, communication, and creativity dimensions. The sixth factor (RC6) comprised a single collaboration item and was excluded from the final model as it did not meet the minimum item requirement for a viable factor (Watkins, 2018).

Table 1 shows five cross-loading items: C5, A9, D7, A18, and B6, each placed within the factor on which it achieved its highest loading, consistent with standard practice (Goretzko et al., 2021; Watkins, 2018). Item B6, which loaded more strongly on the excluded sixth factor, was reassigned to the third factor.

Table 1. EFA Results Based On Polychoric Correlation Analysis

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Uniq
A15	0.992						0.005
A6	0.973						0.036
A2	0.953						0.120
C8	0.917						0.243

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	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Uniq
C4	0.707						0.002
C6	0.707						0.002
A16	0.695						0.293
C5	0.671		0.406				0.113
A13	0.671						0.253
A9	0.480			0.620			0.171
A12	0.436						0.490
D12		0.985					0.042
D1		0.951					0.040
D10		0.940					0.238
D6		0.842					0.267
D7		0.682			0.462		0.005
A18		0.401			0.470		0.450
B2			0.992				0.003
B3			0.992				0.003
B6			0.528			0.536	0.323
B11			0.426				0.811
B4			0.413				0.719
A7				0.892			0.165
A10				0.842			0.221
C3				0.830			0.342
C1				0.425			0.538
D13					0.547		0.692
D4					0.513		0.450
C7					0.491		0.434
D8					0.468		0.806

Note. Applied rotation method is promax.

The five retained factors were named according to their constituent items. Factor 1 is Effective Communication Skills and Critical Thinking (ECS-CT); Factor 2 is Expressing Creativity Skills (ECS); Factor 3 is Collaboration Skills (ColS); Factor 4 is Communication Skills in Problem-Solving (CSPs); and Factor 5 is Creating Skills (CS). All five factors demonstrated satisfactory construct validity. Factor loadings were as follows: ECS-CT, 0.436–0.992; ECS, 0.682–0.985; ColS, 0.413–0.992; CSPs, 0.425–0.892; and CS, 0.468–0.547. These values consistently meet or exceed conventional psychometric standards, supporting the structural integrity of the Four Cs measurement model.

Internal consistency was assessed using Cronbach's alpha. The overall model reliability was $\alpha = 0.884$. Factor-level reliability was: ECS-CT, $\alpha = 0.912$; ECS, $\alpha = 0.856$; ColS, $\alpha = 0.716$; CSPs, $\alpha = 0.796$; and CS, $\alpha = 0.544$. Although the CS factor falls below the conventional threshold of .70, it is retained on the basis of Taber's (2016) classification, in which $\alpha = .544$ is categorized as acceptable. The five factors are therefore considered to have adequate reliability for measurement purposes. The description of the five measurement factors of the Four Cs, including the number and names of the items that constitute them, is summarized in Table 2. The factors to measure the Four Cs.

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Table 2. The Factors To Measure The Four Cs Of Lower-Grade Primary Students

Factor of The Four Cs	Factor Item	Kode
Effective Communication Skills and Critical Thinking (ECS-CT)	Validating (A15)	ECS-CT-1
	Applying the results of reflection (A6)	ECS-CT -2
	Connecting information/experience (A2)	ECS-CT -3
	Asking context-appropriate questions (C8)	ECS-CT -4
	Speaking fluently (C4)	ECS-CT -5
	Responding to a friend's opinion (C6)	ECS-CT -6
	Listening to others' opinions until they finish (A16)	ECS-CT -7
	Listening to other people's perspectives (C5)	ECS-CT -8
	Concluding based on data (A13)	ECS-CT -9
	Interpreting data (A12)	ECS-CT -10
Expressing Creativity Skills (ECS)	Generating original ideas (D12)	ECS-1
	Articulate ideas or thoughts with clarity (D7)	ECS-2
	Enthusiastic about new challenges/experiences (D1)	ECS-3
	Responsive to diverse thoughts (D10)	ECS-4
	Skilled in implementing ideas (D6)	ECS-5
Collaboration Skills (ColS)	Responsible for completing tasks (B2)	ColS-1
	Participating in providing assistance (B3)	ColS-2
	Self-control/compromise (B6)	ColS-3
	Reminding about the agreement/ reprimanding (B11)	ColS-4
	Abiding by the agreement (B4)	ColS-5
Communication Skills in Problem-solving (CSPs)	Explaining the problem (A9)	CSPs-1
	Making an assessment (A7)	CSPs -2
	Telling data/information (A10)	CSPs -3
	Speaking with clear articulation (C3)	CSPs -4
	Expressing opinions according to context (C1)	CSPs -5
Creating Skills (CS)	Arguing (A18)	CS-1
	Curious/enthusiastic about the results (D13)	CS-2
	Modifying and developing ideas (D4)	CS-3
	Responding/expressing agreement or disagreement (C7)	CS-4
	Dare to explore the unknown (D8)	CS-5

Discussion

EFA reveals that among lower-grade primary students, critical thinking and problem-solving do not operate as independent competency clusters but converge through communication, yielding two distinct factors: ECS-CT and CSPs. This structure is theoretically coherent from a Piagetian perspective. At the concrete operational stage (ages 7–11), children reason inductively from perceptible reality, performing logical operations anchored to tangible objects and immediate experience (McLeod, 2025; Cherry, 2024). Because these operations remain externally scaffolded rather than fully internalized, critical thinking is constituted through, rather than merely expressed by communicative interaction. Consequently, both critical thinking and problem-solving manifest statistically as extensions of communication (Slavin, 2018).

Vygotsky's sociocultural theory further illuminates this pattern. Within the zone of proximal development, higher-order thinking emerges through social interaction before becoming internalized as independent thought (Daniels, 2016). For younger students, peer dialogue is not supplementary to cognition; it is the mechanism through which reasoning is constructed and refined. When students exchange perspectives, Piagetian assimilation and accommodation are activated: new information is integrated into existing schemata or

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E-ISSN: 2442-7667
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prompts their restructuring, advancing critical thinking and problem-solving simultaneously (McLeod, 2025).This explains why critical thinking, characterized as the analysis of information, evaluation of arguments, and consideration of multiple perspectives, aligns precisely with communication-dependent learning processes at this developmental stage (Bialik et al., 2016).

A concrete illustration from this study is the "moving water" constructive game challenge, in which students must transfer water to multiple containers at varying distances without leaving their standing positions. Effective communication is essential: students who articulate clear and convincing reasoning influence team decisions, accelerate mutual understanding, and enhance problem-solving effectiveness. This contextual, meaning-embedded communication, occurring through discussion, information exchange, and Q&A is developmentally appropriate, as concrete operational students conclude from observable phenomena through inductive reasoning (De Koning et al., 2002). Consequently, a supportive learning environment is necessary for communication to optimally develop students' critical thinking through direct interaction with their surroundings.

The dimension of creativity is divided into two factors: expressing creativity skills (ECS) and creating skills (CS), collectively reflecting what Beghetto & Kaufman (2007) ;term mini-c simple creativity aligned with students' cognitive developmental level. The ECS factor involves a responsive attitude toward diverse thoughts, enthusiasm for challenges, the ability to generate original ideas, and the capacity to articulate and implement ideas clearly (Ershadi & Winner, 2020). From a Piagetian perspective, ECS represents students' responses to cognitive conflicts requiring schema adjustment (Cherry, 2024). In the moving water challenge, for instance, students must adapt their initial strategies when constrained to a single tool, learning to reorganize ideas according to existing knowledge patterns while accommodating new situational demands.

This adaptive capacity leads to creating skills (CS), which encompass exploring new possibilities, responding to peers' ideas, and demonstrating the courage to modify and argue for collective solutions. These skills develop through experimentation and direct experience involving assimilation and accommodation. As Hennessey & Amabile (2010) assert, the willingness to try new things is foundational to original and innovative production, without courage, students are unlikely to generate unique outcomes.

The collaboration factor (ColS), comprising responsibility, peer assistance, self-control, compromise, and adherence to team agreements, aligns with students' social development at the concrete operational stage, during which egocentrism recedes, and perspective-taking emerges (Santrock, 2018). In Piagetian theory, this corresponds to decentration: the capacity to consider multiple viewpoints simultaneously (Cherry, 2024; Forman, George E.|Kuschner, 1977). Decentration is observable in the moving water challenge when students relinquish their preferred tool in favor of team consensus, or yield an enjoyable role to allow a peer to participate, balancing personal preferences against group goals to reach collective solutions that support coordination and shared purpose (Lai et al., 2017).

Overall, the five EFA-identified factors are interconnected. Each competency dimension interacts with and contributes to the development of the others, consistent with Zhang (2019) assertion that a developing skill aids the development of other skills. Consequently, measuring the Four Cs should be conducted integratively to avoid overlapping items and to capture how these skills develop simultaneously (OECD, 2019). Assessments encompassing multiple interdependent skills are also more effective in preparing students for future workforce demands (Adamson & Darling-Hammond, 2015).

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Implications of the Measurement Factors of The Four C's

Skills are learned abilities, encompassing both mental proficiency and physical dexterity that, once mastered, are performed naturally and often unconsciously (Zhang, 2019). This unconscious quality renders self-report methods such as interviews insufficient for their assessment; direct observational measurement by trained evaluators is methodologically necessary to capture authentic skill execution.

The five factors derived from this study: ECS-CT, CSPs, ECS, ColS, and CS constitute a theoretically grounded and developmentally appropriate assessment framework for students aged seven to nine years. Each factor contains items specifically calibrated to the cognitive and behavioral characteristics of lower-grade primary students, ensuring that measurement reflects genuine developmental capacity rather than abstract competency descriptors. Because the factors are interdependent, items within one factor can stimulate competencies across others problem-based, exploratory, and collaborative learning approaches are recommended as the most effective pedagogical contexts for holistically activating all dimensions simultaneously.

Operationally, the framework is best implemented through structured observational checklists during the learning process, with teachers evaluating both the frequency and quality of each item's manifestation. Greater behavioral frequency within a factor indicates higher skill attainment on that dimension; broader item coverage across all five factors reflects stronger overall Four Cs development. To systematize proficiency judgment, teachers may apply a five-level classification: beginner, advanced beginner, competent, proficient, and expert (Geisinger, 2016), providing a rigorous and actionable continuum for monitoring the integrated development of Four Cs competencies in early primary education.

Conclusion

This study identifies five factors underlying the measurement of the Four Cs in lower-grade primary school students: effective communication and critical thinking (ECS-CT), expressing creativity (ECS), collaboration (ColS), communication in problem-solving (CSPs), and creating skills (CS). Critical thinking and problem-solving develop optimally through effective communication, enacted through talk, discussion, and questioning. Openness to new ideas and the courage to experiment support students in producing original works, driven by intrinsic motivation expressed as enthusiasm. Although collaboration appears as a standalone factor, it functions as the environment within which communication is refined, contributions of ideas sharpen critical thinking and problem-solving, and openness to diverse viewpoints enriches creativity.

Recommendation

Future research should prioritize Confirmatory Factor Analysis (CFA) to rigorously validate the five-factor structure across broader and more diverse populations. Particular attention should also be directed toward refining the Creating Skills (CS) factor, which returned a relatively low Cronbach's alpha, indicating insufficient internal consistency and representing the instrument's most critical psychometric limitation.

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